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Impact of Mesh Fixation Methods on Chronic Pain and Postoperative Quality of Life Following Inguinal Hernia Repair: A Single-Centre Retrospective Study Based on Propensity Score Matching

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Abstract

Background

To compare penetrating versus non-penetrating mesh fixation in inguinal hernia repair in terms of chronic pain and quality of life, and to explore factors associated with chronic postoperative pain.

Methods

This single-centre retrospective cohort study enrolled adults who underwent inguinal hernia repair at Chifeng Cancer Hospital between January 2018 and January 2024, whose fixation method was documented intraoperatively and who completed ≥ 6 months of follow-up. Patients were assigned to a penetrating group (suture or tacker) or a non-penetrating group (glue or self-gripping mesh), with propensity score matching (PSM) to control for confounders. Baseline characteristics, perioperative outcomes, pain visual analogue scale (VAS) scores before surgery and at 3 and 6 months postoperatively, and Carolinas Comfort Scale (CCS) scores at 6 months postoperatively were compared between groups. Logistic regression was used to explore factors associated with chronic postoperative pain, with rare events logistic regression and Poisson regression as sensitivity analyses.

Results

Of 249 patients assessed, 175 were included and, before matching, 117 and 58 were enrolled in the penetrating and non-penetrating groups, respectively; after PSM, 98 and 49 were analysed. Before matching the groups differed in age distribution, whereas after matching no baseline variable differed significantly. Perioperative outcomes—surgical approach, operation time, length of hospital stay, mesh type, and complications—did not differ significantly between groups. The incidence of chronic postoperative pain was higher in the penetrating than in the non-penetrating group (8.2% vs 4.1%), but not significantly so ($P = 0.497$). VAS scores at 3 and 6 months postoperatively and the total and several domain scores of the CCS at 6 months postoperatively favoured the non-penetrating group (all $P < 0.05$). In the multivariable logistic regression, non-penetrating fixation and a lower preoperative VAS score were each associated with lower odds of chronic postoperative pain, and the direction of effect was consistent across sensitivity analyses. Because only 2 chronic pain events occurred in the non-penetrating group, however, these findings are exploratory.

Conclusions

Non-penetrating mesh fixation may offer advantages in reducing chronic postoperative pain and improving quality of life. Fixation method and preoperative VAS score were associated with chronic pain,

suggesting that fixation strategies should be optimised according to individual patient characteristics; these associations are hypothesis-generating, however, given the small number of chronic pain events.

Background

Inguinal hernia is among the most common conditions treated by general surgeons. Minimally invasive techniques and prosthetic materials have advanced considerably over the past two decades, and surgical outcomes have improved in step. Laparoscopic repair, individualised operative planning, and standardised perioperative care have together reduced surgical trauma, shortened recovery, and lowered recurrence rates.

Tension-free mesh repair is now the preferred treatment for inguinal hernia[1]. Its advantages over conventional sutured repair in preventing complications and promoting recovery are well established. Chronic pain, however, has emerged as a principal threat to long-term outcome, with a reported incidence above 10%[2]. Many patients experience discomfort of varying severity for months or years after surgery, and their quality of life suffers accordingly[3]. The cause appears multifactorial: mesh material, biocompatibility, fixation method, and nerve management all contribute[4]. Chronic postoperative pain remains one of the more intractable problems in hernia surgery.

The literature has begun to map the factors associated with chronic pain, but no consensus has emerged on how mesh fixation method influences postoperative pain and comfort. Non-penetrating techniques such as glue and self-gripping mesh are being adopted clinically with increasing frequency, yet which technique best reduces the risk of chronic pain remains an open question. We therefore used propensity score matching to compare penetrating and non-penetrating fixation in patients treated at our centre. Our aims were threefold: to characterise the association of fixation method with chronic pain and quality of life, to identify factors associated with chronic postoperative pain, and to inform the optimisation of clinical fixation technique.

Methods

1. Patient screening and data acquisition. This was a single-centre, retrospective cohort study that enrolled adult patients who underwent inguinal hernia repair at Chifeng Cancer Hospital between January 2018 and January 2024. The inclusion criteria were: (1) age ≥ 18 years; (2) intraoperative explicit documentation of the mesh fixation method (including suture, tacker, glue, or self-gripping mesh); (3) a postoperative follow-up of no less than 6 months, with completion of the postoperative chronic pain and quality of life assessment scales, including the pain visual analogue scale (VAS)[5] and the Carolinas Comfort Scale (CCS)[6]. The exclusion criteria were: (1) concomitant other types of abdominal wall hernia or recurrent inguinal hernia; (2) failure to undergo mesh repair; (3) intraoperative discovery of a special or complex hernia type, such as giant hernia, incarcerated hernia, or sliding hernia; (4) hernia recurrence or reoperation within 6 months postoperatively; (5) incomplete follow-up data or missing VAS or CCS scores.

All relevant clinical data were extracted from the hospital electronic medical record system and the follow-up database, and mainly included basic demographic characteristics (such as age, sex, and preoperative comorbidities), hernia type, surgical approach, mesh type, mesh fixation method, and postoperative complications. According to the intraoperatively documented mesh fixation method, patients were divided into a penetrating fixation group (suture or tacker) and a non-penetrating fixation group (glue fixation or self-gripping mesh). Postoperative chronic pain and quality of life were assessed using the VAS and CCS. VAS scores were evaluated before surgery and at 3 and 6 months postoperatively; CCS scores were obtained at 6 months postoperatively through outpatient or telephone follow-up. Data were collected independently by two investigators, and in the final verification process, any inconsistency in the data was adjudicated and confirmed by a third senior surgeon. As this was a retrospective study, approval was obtained from the institutional ethics committee, which confirmed that an ethical waiver was applicable (ethics approval number: 2025 New No. 23). All included data were strictly de-identified before analysis.

2. Surgical approach and perioperative management. All operations were performed by a surgical team at our centre qualified in the treatment of inguinal hernia. Aseptic technique was strictly observed, and procedures followed the relevant surgical standards in the *International Guidelines for Groin Hernia Management* (HerniaSurge Group, 2018)[7]. All patients undergoing open surgery received standard Lichtenstein tension-free hernioplasty[8]. The hernia sac and the posterior wall of the inguinal canal were exposed through an inguinal incision. After adequate mobilisation and reduction of the sac, a polypropylene mesh was placed between the transversalis fascia and the internal oblique muscle, and fixation was performed according to the assigned method—penetrating (suture or tacker) or non-penetrating (glue or self-gripping mesh). Minimally invasive approaches comprised transabdominal preperitoneal repair (TAPP)[9] or totally extraperitoneal repair (TEP)[10]. Under laparoscopy, the preperitoneal space was entered and the tissues of the inguinal region dissected; the mesh was then implanted and fixed according to the preoperative plan. The meshes used were Bard® 3D Max Light (C.R. Bard, USA) and Parietex™ mesh (Medtronic, France); models and production lots were recorded intraoperatively. The surgeon selected the mesh according to the patient's condition and intraoperative findings, and the distribution of mesh types did not differ significantly between groups.

All patients underwent a baseline pain assessment before surgery covering history of chronic pain, pain sensitivity, and analgesic requirement. Postoperative analgesia was multimodal and typically comprised oral nonsteroidal anti-inflammatory drugs (NSAIDs), supplemented when necessary with intravenous analgesics. Analgesia was adjusted dynamically against postoperative VAS scores to keep the score at or below 3. Postoperative complications were graded using the Clavien–Dindo classification. Grade I–II complications were managed conservatively or supportively; grade III or higher complications were managed after multidisciplinary team review. Patients were discharged once vital signs were stable, eating and urination were independent, the wound had healed well, and the VAS score was ≤ 3 after analgesia.

3. Study endpoints and criteria for the assessment of pain and quality of life. The primary endpoint of this study was the occurrence of chronic postoperative pain. In accordance with the recommendations of the International Association for the Study of Pain (IASP)[11] and the International Guidelines for Groin Hernia Management (HerniaSurge Group, 2018)[7], chronic postoperative pain was defined as pain in the surgical area persisting for more than 3 months after surgery without a clear organic cause. In this study, a VAS score of ≥ 3 was used as the criterion for chronic pain; all scores were recorded as integers and incorporated into the disease course and study analysis. The secondary endpoints included: (1) postoperative perioperative indicators, such as length of hospital stay and the incidence of postoperative complications; (2) changes in pain scores at different time points; and (3) quality of life scores at 6 months postoperatively.

Pain intensity was assessed using the visual analogue scale (VAS). The VAS is a subjective pain scale on which patients mark their own degree of pain on a continuous line of 0–10 cm, where 0 indicates no pain and 10 indicates unbearable severe pain. VAS scores were completed under the guidance of medical staff before surgery and at 3 and 6 months postoperatively, and were used to document the trend of postoperative pain. Pain severity was graded as follows: 0, no pain; 1–3, mild pain; 4–6, moderate pain; and 7–10, severe pain. Quality of life was assessed using the Carolinas Comfort Scale (CCS), which is primarily used to evaluate functional recovery and subjective discomfort in patients after inguinal hernia surgery and covers eight activity domains: lying down, sitting, walking, bending over, climbing stairs, coughing or sneezing, dressing, and overall impact; the seven activity domains other than overall impact are reported separately below. Each item is scored from 0 (no discomfort) to 5 (severe impact). The CCS was assessed across three dimensions—pain, activity limitation, and foreign-body sensation of the mesh; in this study, the mean of the scores across these three aspects was taken as the quality of life indicator, and was collected at 6 months postoperatively through outpatient or telephone follow-up.

4. Statistical methods. All analyses were performed in R (version 4.3.2, The R Foundation). Continuous variables were assessed for normality. Normally distributed variables are reported as mean ± standard deviation ($\bar{x} \pm s$) and were compared using Welch's unequal-variance t-test, which does not assume equal variances between groups; non-normally distributed variables are reported as median (interquartile range) and were compared using the Mann–Whitney U test. Categorical variables are reported as frequencies (percentages) and were compared using the χ^2 test or, where the expected frequency in any cell was < 5, Fisher exact test. All tests were two-sided, and $P < 0.05$ was considered statistically significant. To limit the influence of baseline imbalances on outcomes, propensity score matching (PSM) was performed by nearest-neighbour matching without replacement, with a caliper of 0.2 and a ratio of penetrating to non-penetrating fixation of 1:2. The matching variables were age, sex, hernia type, comorbidity, and ASA score. Balance before and after matching was assessed using the standardised mean difference (SMD) and displayed as a Love plot. Adequate covariate balance after PSM was a prerequisite for the subsequent comparative analyses.

For VAS scores at the postoperative time points and CCS scores at 6 months, between-group differences were tested and radar plots generated to show how the two groups differed across scoring domains.

Factors associated with chronic pain were examined by logistic regression, with univariate and multivariable models fitted separately and the odds ratio (OR), 95% confidence interval (CI), and P value reported. Because the overall incidence of chronic pain was low, a conventional logistic model could be subject to small-sample bias at low event rates, yielding unstable OR estimates; rare events logistic regression[12] and Poisson regression[13] were therefore added as sensitivity analyses.

Because the number of chronic pain events was small, the regression estimates reported here are exploratory and hypothesis-generating rather than confirmatory. The study was powered primarily for the between-group comparisons of VAS and CCS scores; the regression analyses describe the direction of association and do not establish independent effects. Events per variable were insufficient to support a stable multivariable model, and the wide confidence intervals around the fixation-method estimate reflect this.

Missing data were handled by complete-case analysis. Patients with incomplete follow-up or missing VAS or CCS data were excluded from the analysis population under exclusion criterion (5). All participants contributing to the analyses reported here therefore had complete data for every variable in Tables 1–6, and no imputation or other missing-data modelling was applied. Loss to follow-up was thus addressed at screening rather than during analysis, and the possibility of attrition bias is acknowledged as a limitation (see Discussion).

Table 1
Baseline characteristics before propensity score matching

Variable	Category	Penetrating group	Non-penetrating group	Test statistic	P value
		(n = 117)	(n = 58)	(t/χ^2)	
Age (years)		53.4 ± 12.7	49.4 ± 11.0	2.14	0.034
Sex	Female	9 (7.7)	3 (5.2)	-	0.751
	Male	108 (92.3)	55 (94.8)		
Hernia type	Direct	97 (82.9)	48 (82.8)	0.001	1
	Indirect	20 (17.1)	10 (17.2)		
Comorbidity	None	71 (60.7)	36 (62.1)	0.017	0.896
	Diabetes mellitus	11 (9.4)	4 (6.9)	-	0.774
	Liver disease	8 (6.8)	0 (0.0)	-	0.052
	Bronchial or pulmonary disease	5 (4.3)	6 (10.3)	2.407	0.121
	Hypertension	9 (7.7)	5 (8.6)	0.039	0.843
	Heart failure or previous myocardial infarction	5 (4.3)	6 (10.3)	2.407	0.121
	Other comorbidity	8 (6.8)	1 (1.7)	-	0.273
ASA score	1	30 (25.6)	22 (37.9)	1.048	0.592
	2	57 (48.7)	29 (50.0)		
	3	30 (25.6)	7 (12.1)		

Data are presented as mean ± standard deviation or n (%). PSM, propensity score matching.

Fisher exact test was used where the expected frequency in any cell was < 5; Fisher exact test does not yield a test statistic, hence "-".

No a priori sample size calculation was performed, because this was a retrospective study that included all consecutive patients meeting the eligibility criteria during the study period. The sample size was therefore determined by the volume of eligible cases available, and the analysis should be regarded as exploratory with respect to the chronic pain endpoint (see below).

5. Reporting guideline and use of writing-assistance tools. This study was conducted and reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement for retrospective cohort studies[14]; the completed STROBE checklist is provided as Additional file 1.

Use of language-editing and writing-assistance tools. The manuscript was originally written in Chinese by the authors. LLM-based tools were used for (i) translation into English, and (ii) language polishing and revision of sentence-level expression. The authors reviewed and verified all AI-assisted output against the original Chinese text and the underlying clinical data. The LLM was not used to generate research data, to perform statistical analyses, to interpret findings, or to formulate conclusions, and it is not listed as an author. Terminology was standardised against established medical nomenclature, and all authors have read and approved the final version and accept full responsibility for its content.

Results

1. Comparison of baseline data before and after PSM. Of 249 patients who underwent inguinal hernia repair during the study period and were assessed for eligibility, 74 were excluded at screening: recurrent or other abdominal wall hernia, n = 12; complex hernia type, n = 17; recurrence or reoperation within 6 months, n = 2; and incomplete follow-up or missing VAS or CCS data, n = 43. No patient was excluded for failure to undergo mesh repair. The remaining 175 patients entered the cohort and, before PSM, comprised 117 in the penetrating group and 58 in the non-penetrating group. Figure 1 shows the flow of participants through screening, group assignment, and propensity score matching.

Before PSM, the two groups differed in age distribution ($P < 0.05$). The remaining baseline characteristics—sex, ASA score, hernia type, and comorbidity—did not differ significantly between groups (Table 1).

After 1:2 nearest-neighbour PSM by fixation method, 98 patients were matched to the penetrating group and 49 to the non-penetrating group, and these 147 patients entered the post-matching analysis. After matching, the SMD was below 0.1 for four of the five matching variables (sex 0.090, hernia type 0.079, comorbidity 0.000, and ASA score 0.061) and no difference was statistically significant, indicating adequate covariate balance for these variables (Table 2). The SMD for age was 0.149, slightly above the conventional 0.1 threshold; this residual imbalance reflects a mean difference of only 1.80 years (51.56 ± 12.42 vs 49.76 ± 11.41 years). Because age showed no association with chronic pain on univariable analysis (OR = 1.079, 95% CI 0.225–4.132, P = 0.780), this small residual difference is unlikely to have confounded the comparison. Balance before and after matching is shown as a Love plot in Fig. 2.

Table 2
Baseline characteristics after propensity score matching

Variable	Category	Penetrating group	Non-penetrating group	Test statistic	P value
		(n = 98)	(n = 49)	(t/χ^2)	
Age (years)		51.56 ± 12.42	49.76 ± 11.41	0.878	0.382
Sex	Female	6 (6.1)	2 (4.1)	-	0.719
	Male	92 (93.9)	47 (95.9)		
Hernia type	Direct	81 (82.7)	39 (79.6)	0.204	0.651
	Indirect	17 (17.3)	10 (20.4)		
Comorbidity	None	56 (57.1)	28 (57.1)	0	1
	Diabetes mellitus	11 (11.2)	4 (8.2)	-	0.774
	Liver disease	8 (8.2)	0 (0.0)	-	0.052
	Bronchial or pulmonary disease	4 (4.1)	6 (12.2)	-	0.084
	Hypertension	6 (6.1)	5 (10.2)	0.786	0.375
	Heart failure or previous myocardial infarction	5 (5.1)	5 (10.2)	1.341	0.247
	Other comorbidity	8 (8.2)	1 (2.0)	-	0.273
ASA score	1	30 (30.6)	16 (32.7)	0.13	0.937
	2	52 (53.1)	26 (53.1)		
	3	16 (16.3)	7 (14.3)		

Data are presented as mean ± standard deviation or n (%). PSM, propensity score matching.

Fisher exact test was used where the expected frequency in any cell was < 5; Fisher exact test does not yield a test statistic, hence "-".

2. Comparison of perioperative outcomes after PSM. Perioperative outcomes after PSM were comparable between groups. Open surgery accounted for 90.8% of the penetrating group and 87.8% of the non-penetrating group (P = 0.563). Operation time did not differ significantly (36.23 ± 10.79 min vs 37.55 ± 12.31 min, P = 0.523), nor did postoperative length of hospital stay (22.38 ± 7.30 h vs 22.85 ± 6.38 h, P = 0.687). Meshes were mainly Bard 3D and Parietex, with no significant difference in distribution (P = 0.329). Perioperative complications occurred in 10.2% of the penetrating group and 8.2% of the non-penetrating group (P = 0.775). Complication types included urinary retention, urinary tract

infection, haematoma or seroma, orchitis or testicular-related problems, wound infection, neuralgia, nonspecific pain, and others; none differed significantly between groups (all $P > 0.05$, Table 3).

3. Assessment and comparison of chronic pain and comfort. The incidence of chronic postoperative pain was higher in the penetrating group than in the non-penetrating group (8.2% vs 4.1%), but the difference was not statistically significant ($P = 0.497$). VAS scores did not differ between groups before surgery (3.7 ± 2.32 vs 3.88 ± 2.85, $P = 0.713$). At 3 months (1.21 ± 1.06 vs 0.86 ± 0.84, $P = 0.028$) and 6 months postoperatively (1.03 ± 0.92 vs 0.45 ± 0.65, $P < 0.001$), scores in the non-penetrating group were significantly lower than in the penetrating group. CCS scores in the non-penetrating group were lower in almost all activity domains, with significant differences in lying down ($P < 0.001$), bending over ($P < 0.001$), climbing stairs ($P = 0.034$), coughing ($P = 0.019$), and dressing ($P = 0.002$), indicating greater postoperative comfort. The total CCS score favoured the non-penetrating group (3.6 ± 1.1 vs 4.94 ± 1.4, $P < 0.001$, Table 4). In the radar plot of VAS scores across the three time points, the non-penetrating group scored consistently lower at both postoperative assessments (Fig. 3). The radar plot of 6-month CCS scores showed better comfort in the non-penetrating group across almost all dimensions (Fig. 4).

4. Analysis of factors associated with chronic pain. On univariate logistic regression, mesh fixation method, sex, ASA score, and preoperative VAS score were associated with chronic postoperative pain ($P < 0.05$ for all; $P < 0.01$ for fixation method). Entered together in a multivariable model, mesh fixation method and preoperative VAS score were the factors most strongly associated with chronic pain. Compared with penetrating fixation, non-penetrating fixation was associated with lower odds of chronic postoperative pain (OR = 0.244, 95% CI: 0.067–0.736, $P = 0.019$); a higher preoperative VAS score was associated with higher odds (OR = 2.913, 95% CI: 1.196–6.073, $P = 0.037$). The remaining variables were not statistically significant (Table 5).

Table 3
Perioperative outcomes after propensity score matching

Variable	Category	Penetrating group	Non-penetrating group	Test statistic	P value
		(n = 98)	(n = 49)	(t/χ^2)	
Surgical approach	Open	89 (90.8)	43 (87.8)	0.334	0.563
	Minimally invasive	9 (9.2)	6 (12.2)		
Operation time (min)		36.23 ± 10.79	37.55 ± 12.31	-0.641	0.523
Postoperative hospital stay (h)		22.38 ± 7.30	22.85 ± 6.38	-0.404	0.687
Mesh type	Bard 3D	66 (67.3)	29 (59.2)	0.952	0.329
	Parietex	32 (32.7)	20 (40.8)		
Perioperative complications		10 (10.2)	4 (8.2)	-	0.775
Complication type	Urinary retention	2 (2.0)	0 (0.0)	-	0.553
	Urinary tract infection	1 (1.0)	1 (2.0)	-	1
	Haematoma or seroma	0 (0.0)	1 (2.0)	-	0.333
	Orchitis or testicular problems	2 (2.0)	1 (2.0)	-	1
	Wound infection	2 (2.0)	0 (0.0)	-	0.553
	Neuralgia	0 (0.0)	0 (0.0)	-	1
	Non-specific pain	2 (2.0)	1 (2.0)	-	1
	Other	1 (1.0)	0 (0.0)	-	1

Data are presented as mean ± standard deviation or n (%). PSM, propensity score matching.

Fisher exact test was used where the expected frequency in any cell was < 5; Fisher exact test does not yield a test statistic, hence “-”.

Table 4
Chronic pain and comfort outcomes

Variable	Category	Penetrating group	Non-penetrating group	Test statistic	P value
		(n = 98)	(n = 49)	(t/χ^2)	
Chronic pain		8 (8.2)	2 (4.1)	-	0.497
VAS score (preoperative)		3.7 ± 2.32	3.88 ± 2.85	-0.37	0.713
VAS score (3 months postoperative)		1.21 ± 1.06	0.86 ± 0.84	2.22	0.028
VAS score (6 months postoperative)		1.03 ± 0.92	0.45 ± 0.65	4.425	< 0.001
CCS domain scores	Lying down	0.73 ± 0.61	0.37 ± 0.36	4.459	< 0.001
	Sitting	0.61 ± 0.66	0.51 ± 0.21	1.435	0.154
	Walking	0.68 ± 0.47	0.56 ± 0.33	1.832	0.069
	Bending over	0.87 ± 0.60	0.40 ± 0.23	6.846	< 0.001
	Climbing stairs	0.52 ± 0.31	0.71 ± 0.60	-2.168	0.034
	Coughing	0.78 ± 0.71	0.56 ± 0.40	2.373	0.019
	Dressing	0.75 ± 0.75	0.49 ± 0.24	3.091	0.002
CCS total score		4.94 ± 1.40	3.60 ± 1.10	6.347	< 0.001

Data are presented as mean ± standard deviation or n (%). PSM, propensity score matching.

CCS, Carolinas Comfort Scale; VAS, visual analogue scale.

Table 5
Univariate and multivariable logistic regression for chronic pain

	Univariate logistic regression			Multivariable logistic regression		
	OR	**95% CI**	**P value**	**OR**	**95% CI**	**P value**
Fixation method	0.129	0.040–0.651	0.004	0.244	0.067–0.736	0.019
Age	1.079	0.225–4.132	0.780			
Sex	5.780	1.277–28.571	0.028	1.031	0.975–6.097	0.306
Hernia type	2.018	0.413–7.844	0.333			
Comorbidity	3.215	0.771–21.739	0.149			
ASA score	3.077	1.149–9.105	0.031	2.119	0.459–5.625	0.483
Surgical approach	0.913	0.603–1.396	0.754			
Operation time	1.017	0.961–1.072	0.536			
Postoperative hospital stay	0.995	0.910–1.095	0.915			
Mesh type	2.967	0.808–12.101	0.105			
VAS score (preoperative)	3.463	1.202–8.111	0.036	2.913	1.196–6.073	0.037
Perioperative complications	1.078	0.389–5.142	0.992			

OR, odds ratio; CI, confidence interval. Univariate P values derive from univariable screening and are not adjusted for multiplicity. Estimates are exploratory and hypothesis-generating given the small number of chronic pain events.

Table 6
Rare events and Poisson regression for chronic pain

	Rare events logistic regression			Poisson regression		
	OR	**95% CI**	**P value**	**OR**	**95% CI**	**P value**
Fixation method	0.472	0.176–0.609	0.032	0.388	0.091–0.593	0.027
Sex	1.209	0.601–4.519	0.579	1.274	0.047–5.038	0.607
ASA score	1.917	0.482–3.824	0.702	2.010	0.585–3.947	0.689
VAS score (preoperative)	1.838	1.084–5.640	0.040	1.935	1.260–4.805	0.042

OR, odds ratio; CI, confidence interval. Estimates are exploratory and hypothesis-generating given the small number of chronic pain events.

These estimates require cautious interpretation. Chronic pain occurred in only 10 patients in the analysis population, 2 of them in the non-penetrating group. With two events in the smaller exposure stratum, the multivariable model was substantially underpowered and the confidence intervals are correspondingly wide. The OR of 0.244 should therefore be read as indicating the direction and plausible range of the association rather than a precisely estimated effect size, and it does not by itself establish non-penetrating fixation as an independent determinant of chronic pain.

Because chronic pain was a low-incidence event, conventional logistic regression may yield unstable estimates under low event rates; rare events logistic regression and Poisson regression were therefore applied as sensitivity analyses. Both identified mesh fixation method and preoperative VAS score as associated with chronic pain, with effect directions consistent with the primary logistic model (all $P < 0.05$; Table 6). This concordance supports the internal consistency of the observed association, but does not overcome the limitation imposed by the small number of events.

Ten patients in this study were diagnosed with chronic postoperative pain. Three experienced marked symptom relief after systematic physiotherapy, including physical therapy, thermotherapy, and neural mobilisation; 6 improved substantially with pharmacological treatment, including NSAIDs and agents used for neuropathic pain such as gabapentin, pregabalin, and tricyclic antidepressants; and the remaining patient, after failure of standard conservative treatment, underwent mesh removal combined with repeat hernia repair and had no obvious discomfort postoperatively.

Discussion

Inguinal hernia is among the most common abdominal wall hernias seen in practice, and its management has moved from conventional sutured repair to tension-free hernioplasty. Tension-free

mesh repair is now a recognised standard of care. Open repair is represented by the Lichtenstein technique and laparoscopic repair by TAPP and TEP; both are widely recommended in consensus documents such as the International Guidelines for Groin Hernia Management[15, 16]. Mesh repair has reduced recurrence substantially, but chronic pain persists in 10%–12% of patients and remains a leading cause of impaired quality of life. Its mechanism is complex, involving operative manipulation, fixation method, individual patient factors, and more. The literature remains inconsistent on this point—particularly on the relationship between fixation method and the risk of chronic postoperative pain—which limits its usefulness for clinical guidance.

The present study therefore grouped patients by fixation method (penetrating versus non-penetrating) and used PSM to adjust for potential confounders. We compared the two methods under balanced baseline conditions and assessed pain severity and quality of life multidimensionally with the VAS and CCS. Our aim was to provide evidence to support the optimisation of mesh fixation strategies and reduce the incidence of chronic pain.

Patients were grouped by whether the fixation method penetrates the tissue. The incidence of chronic postoperative pain did not differ significantly between groups (8.2% vs 4.1%, P = 0.497), although the point estimate was lower with non-penetrating fixation. In the regression models, non-penetrating fixation was associated with lower odds of chronic pain after adjustment for preoperative VAS score. Because only two chronic pain events occurred in the non-penetrating group, however, this association is best treated as a hypothesis-generating signal rather than as evidence of an independent protective effect. The direction of the association is broadly consistent with much of the previous literature. In a meta-analysis of 18 randomised controlled trials (RCTs) and 2312 patients, glue fixation reduced haematoma, acute pain, and chronic pain relative to tackers, and shortened the time to resumption of daily activities or work, with a mean difference in chronic pain VAS scores of up to 0.42[17]. A further study identified fixation type as an important predictor of postoperative pain scores and linked self-gripping polyester mesh to lower pain severity[18].

Other reports diverge from this picture. A meta-analysis comparing cyanoacrylate glue with suture fixation found that glue reduced early postoperative pain but made no statistically significant difference to the incidence of chronic pain[19]. Beyond fixation method, several studies have examined specific mesh types. Novel self-gripping meshes such as the ProFlor 3D dynamic regenerative scaffold[20] and specialised biomaterial meshes[21] have been reported to offer advantages over conventional meshes in relieving chronic postoperative pain and foreign-body sensation.

Discrepancies among studies may arise from differences in design and comparator, heterogeneity of enrolled populations, inconsistent criteria for assessing chronic postoperative pain, and the continuing evolution of mesh materials and surgical technique. Chronic postoperative pain is highly subjective and its assessment is not standardised, so studies from different periods and regions may vary considerably. Comparisons restricted to mesh type are also unlikely to yield conclusions of broad applicability. One further consideration applies specifically to the present study: statistical power. With only 10 chronic

pain events overall and 2 in the non-penetrating group, events per variable fell far below the conventional threshold of 10 for stable multivariable modelling. Estimates derived under these conditions are prone to bias and wide confidence intervals, and the apparent significance of the fixation-method term should not be over-interpreted. The direction observed here is consistent with the biological rationale that avoiding tissue penetration may reduce nerve entrapment and inflammatory irritation. Confirming it would require a considerably larger sample or a pooled analysis.

The VAS and CCS comparisons between groups, by contrast, reached statistical significance at several time points. These analyses concern continuously distributed scores in a larger number of patients and therefore rest on firmer statistical ground than the event-based regressions. The contrast is itself informative: fixation method may be more reliably detected through graded symptom scores than through the binary occurrence of chronic pain.

This study and several existing reports suggest that non-penetrating fixation offers advantages in reducing the risk of chronic postoperative pain. Individualisation should nonetheless remain central to clinical decision-making. Age, occupation, and whether the hernia is bilateral or recurrent all shape the perceived intensity of postoperative pain and the course of functional recovery. For younger patients and those in manual work, non-penetrating fixation may improve comfort and speed functional recovery; where anatomy is complex or recurrence risk is higher, penetrating fixation may provide greater stability of the repair. The choice should therefore be made with repair efficacy and recurrence control as prerequisites, taking full account of the patient's clinical characteristics and intraoperative findings, and avoiding a one-size-fits-all approach.

The temporal evolution of chronic postoperative pain and its effect on long-term function also deserve attention. Follow-up in some earlier studies was relatively short, with pain assessment largely confined to 3–6 months postoperatively, which may underestimate delayed-onset pain and the duration of persistent symptoms. This study assessed discomfort with the CCS at 6 months, but a single measurement at that point cannot fully capture the long-term evolution and functional impact of chronic pain. Chronic pain may change dynamically in response to postoperative mesh fibrosis, neural remodelling, or scar traction. Future studies should therefore extend follow-up beyond 1 year, and combine quality of life scales, functional recovery scores, and measures of social participation to characterise more systematically how fixation method affects chronic pain and overall quality of life.

This study also found a significant association between preoperative VAS score and the occurrence of chronic postoperative pain, suggesting that preoperative pain status may predict long-term postoperative pain perception. This is consistent with a previous retrospective study[22]. Systematic research on factors associated with chronic postoperative pain remains limited, however. Factors identified in the literature include the degree of inflammatory response in the surgical area, poorly controlled early postoperative pain, nerve injury potentially induced by lateral fixation of the mesh near the deep inguinal ring, intraoperative ischaemic tissue damage, and the irritating effect of certain fixation materials such as fibrin sealant on nerves[23–27]. Future work should integrate these factors and

combine mechanistic studies with clinical data, to support earlier identification of, and intervention in, chronic pain.

Future research directions. Although this study controlled for confounders through propensity score matching and tested the robustness of the results across several statistical models, important limitations remain. First, the single-centre, retrospective design may limit the generalisability of the conclusions, and multicentre prospective studies with larger samples are warranted. Second, the absence of subgroup analyses in high-risk populations such as bilateral or recurrent hernia limits the evaluation of individualised fixation strategies. Future work should extend follow-up and adopt more comprehensive instruments, including EQ-5D, SF-36, and neuropathic pain scales such as DN4. Interaction analyses of novel meshes and fixation methods would help clarify their long-term effects on chronic pain, functional recovery, and quality of life, and imaging and biomarkers could further elucidate pain mechanisms, providing a basis for precision treatment.

Limitations of this study. Several limitations should be borne in mind. As a single-centre retrospective study, this work controlled for baseline differences as far as possible through propensity score matching, but selection and information bias may persist and limit causal inference. Second—and most importantly—the number of chronic pain events was very small: 10 in total, and only 2 in the non-penetrating group. The multivariable regression analyses are therefore limited in reliability and should be regarded as exploratory and hypothesis-generating rather than definitive. The reported odds ratios carry wide confidence intervals and are sensitive to the small number of events; the finding that non-penetrating fixation was most strongly associated with chronic pain requires confirmation in larger samples before it can inform clinical decisions.

Further limitations concern measurement and follow-up. Chronic pain was assessed from patients' subjective reports; standardised instruments (VAS and CCS) were used, but individual differences in perception remain unavoidable and may introduce measurement bias. All enrolled patients were followed for at least 6 months postoperatively, in line with the international definition of chronic pain, but the absence of longer-term follow-up precludes assessment of pain persistence and its long-term effect on quality of life. A further caveat concerns covariate balance: although propensity score matching reduced baseline differences substantially, the SMD for age remained marginally above the conventional 0.1 threshold after matching (0.149), so a small degree of residual confounding by age cannot be excluded. This imbalance corresponded to a mean difference of less than two years and age was not associated with chronic pain in univariable analysis, which limits but does not entirely eliminate this concern. Some patients were excluded for incomplete follow-up, which may introduce attrition bias. Finally, specific fixation materials (glue type, suture material, and different models of self-gripping mesh) were not distinguished, which limits a refined analysis of how technique and material details affect postoperative pain and narrows the scope of the conclusions. These constraints mean the findings should be read as supporting a plausible direction of effect that warrants prospective confirmation, not as establishing a causal relationship.

Conclusions

Non-penetrating mesh fixation may offer advantages in reducing the incidence of chronic postoperative pain and improving quality of life after inguinal hernia repair. In this cohort, patients who received non-penetrating fixation reported lower VAS scores at 3 and 6 months postoperatively and better CCS scores at 6 months than those who received penetrating fixation; these differences were statistically significant. Fixation method and preoperative VAS score were the factors most strongly associated with chronic pain in the regression models, suggesting that fixation strategies should be optimised according to individual patient characteristics.

These conclusions should nevertheless be interpreted with caution. The number of chronic pain events was small—10 overall, of whom only 2 were in the non-penetrating group—so the regression-based findings, including the apparent protective association of non-penetrating fixation, are hypothesis-generating rather than definitive. They require confirmation in larger studies, preferably multicentre and prospective, with longer follow-up. The between-group comparisons of VAS and CCS scores rest on continuously distributed measures in a larger number of patients and therefore on firmer statistical ground; these provide the more reliable of the present findings.

Abbreviations

ASA
American Society of Anesthesiologists
CCS
Carolinas Comfort Scale
CI
confidence interval
CPIP
chronic postoperative inguinal pain
CRediT
Contributor Roles Taxonomy
EQ-5D
EuroQol 5-Dimension questionnaire
IASP
International Association for the Study of Pain
LLM
large language model
NSAIDs
nonsteroidal anti-inflammatory drugs
OR
odds ratio
PSM

propensity score matching
RCT
randomised controlled trial
SD
standard deviation
SF-36
36-Item Short Form Health Survey
SMD
standardised mean difference
STROBE
Strengthening the Reporting of Observational Studies in Epidemiology
TAPP
transabdominal preperitoneal repair
TEP
totally extraperitoneal repair
VAS
visual analogue scale

Declarations

Ethics approval and consent to participate

This study was approved by the Medical Ethics Committee of Chifeng Cancer Hospital (□□□□□□□□□□□□□□□□) (approval number: 2025 New No. 23). Because of the retrospective design, the requirement for written informed consent was waived by the ethics committee. All data were de-identified before analysis.

Consent for publication

Not applicable. This manuscript does not contain any individual person's data in any form, including individual details, images, or videos.

Competing interests

The authors declare that they have no competing interests.

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Author Contribution

R.L. and H.L. conceived and designed the study. R.L., H.G., T.W., and M.L. contributed to data acquisition and data curation. R.L. and H.G. performed the statistical analysis. R.L. drafted the manuscript. H.L. critically revised the manuscript for important intellectual content. All authors read and approved the final manuscript and agree to be accountable for all aspects of the work.

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Data Availability

The datasets generated and analysed during the current study are not publicly available because they contain identifiable patient information obtained from hospital medical records, but are available from the corresponding author on reasonable request.

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Figures

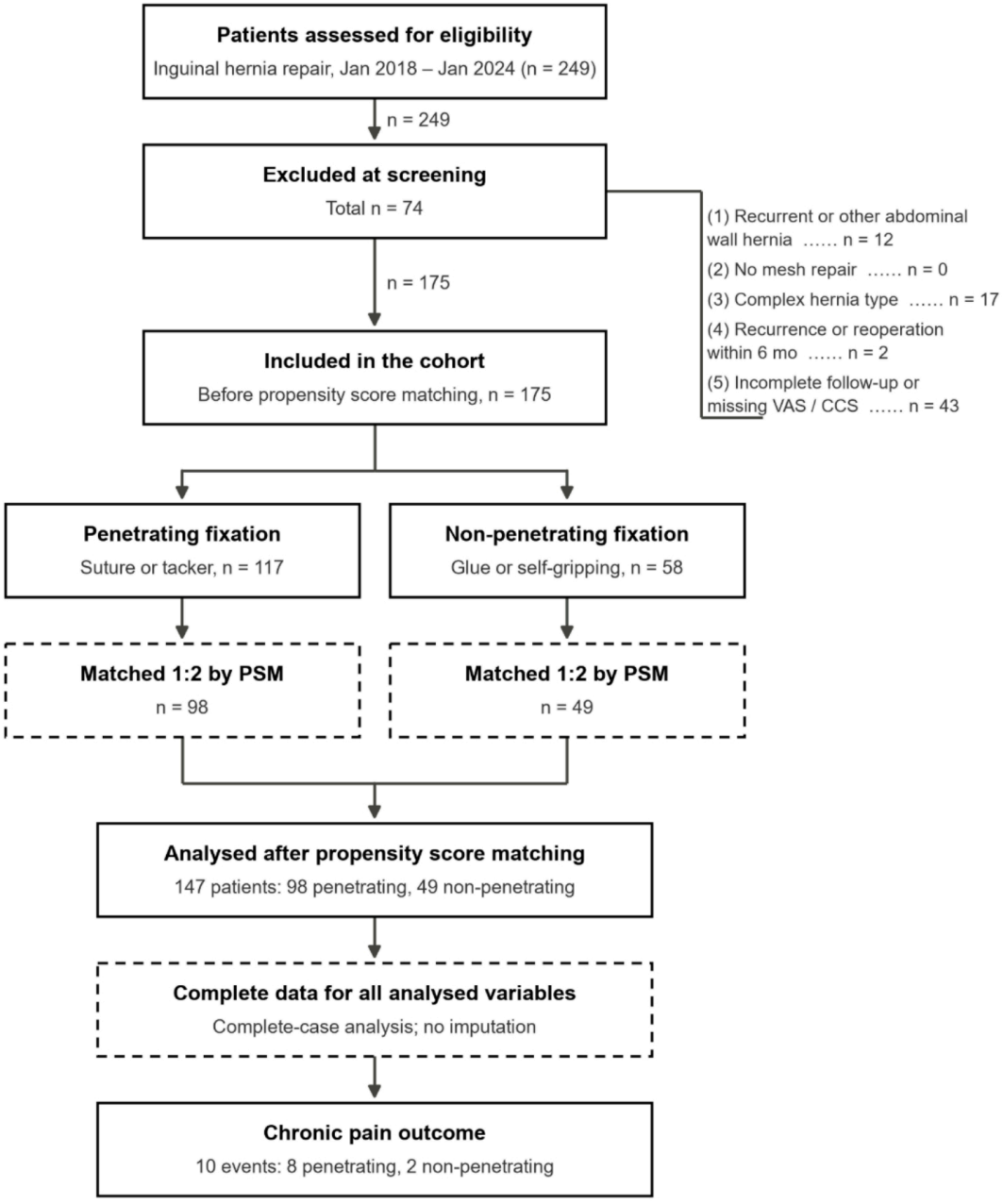


Figure 1

Participant flow diagram. A total of 249 adults undergoing inguinal hernia repair between January 2018 and January 2024 were assessed for eligibility. Of these, 74 were excluded at screening: recurrent or other abdominal wall hernia (n = 12), complex hernia type such as giant, incarcerated, or sliding hernia (n = 17), recurrence or reoperation within 6 months (n = 2), and incomplete follow-up or missing VAS or CCS data (n = 43); no patient was excluded for failure to undergo mesh repair. The remaining 175 patients were assigned to the penetrating fixation group (suture or tacker, n = 117) or the non-penetrating

fixation group (glue or self-gripping mesh, n = 58) according to the intraoperatively documented fixation method, and were then matched 1:2 by propensity score, yielding 98 and 49 patients, respectively. The 147 matched patients had complete data for every variable analysed and constituted the analysis population, in which 10 chronic pain events occurred (8 penetrating, 2 non-penetrating).

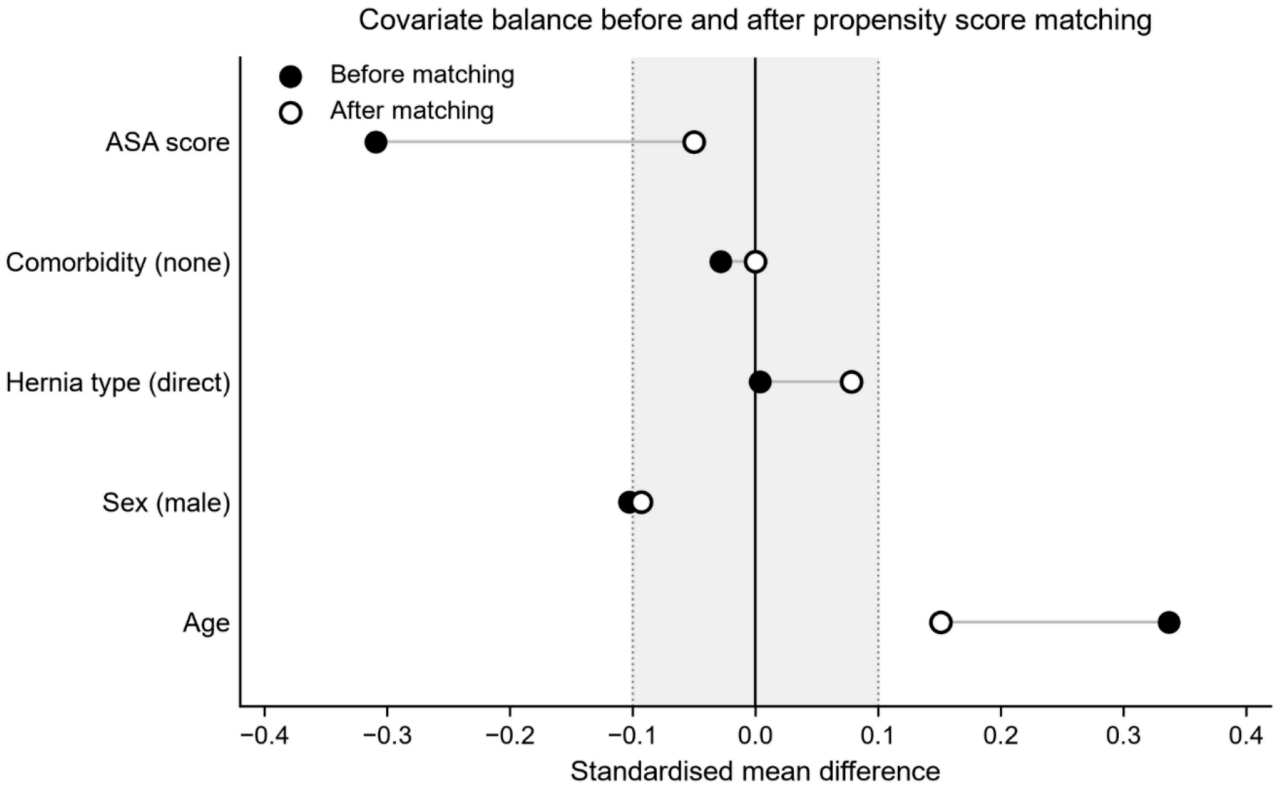


Figure 2

Love plot of covariate balance before and after propensity score matching. Each panel shows, for one baseline variable (age, sex, hernia type, comorbidity, and ASA score), the standardised mean difference (SMD) between the penetrating and non-penetrating groups before matching (filled circles) and after matching (open circles); the grey band marks the conventional |SMD| < 0.1 threshold for adequate balance. Standardised mean differences were derived from the baseline characteristics presented in Table 1 (before matching) and Table 2 (after matching): for continuous variables as the difference in means divided by the pooled standard deviation, and for categorical variables from the difference in proportions. Most variables moved into or towards the 0.1 band after matching, indicating improved covariate balance.

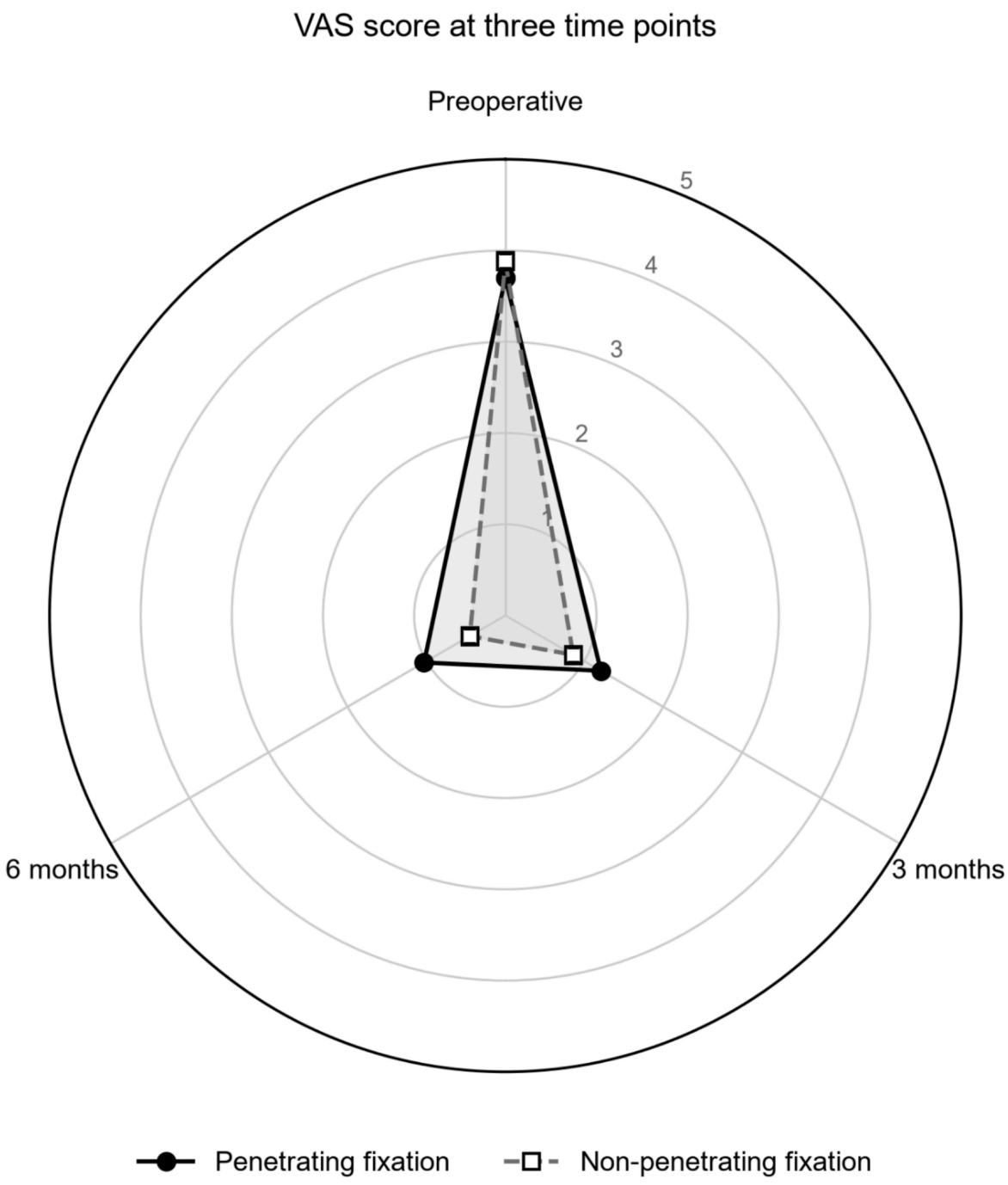


Figure 3

Radar plot of VAS scores at three time points. VAS scores are shown in the penetrating and non-penetrating fixation groups before surgery and at 3 and 6 months postoperatively. The preoperative scores of the two groups were similar; at 3 and 6 months postoperatively, VAS scores in the non-penetrating group were consistently lower than those in the penetrating group, suggesting better postoperative pain relief.

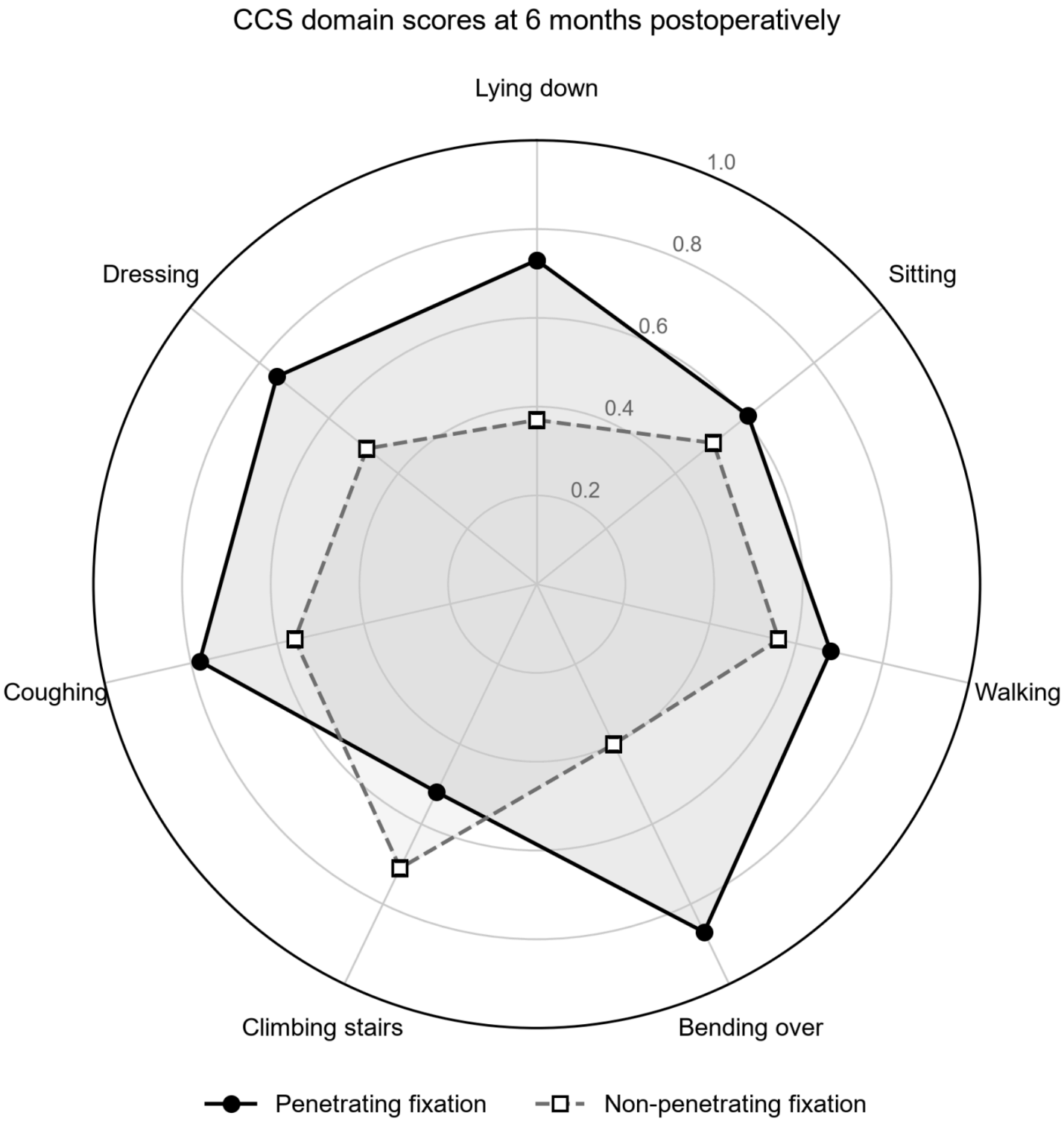


Figure 4

Radar plot of CCS scores at 6 months postoperatively. The non-penetrating fixation group scored lower than the penetrating fixation group in the domains of lying down (P<0.001), bending over (P<0.001), climbing stairs (P=0.034), coughing (P=0.019), and dressing (P=0.002), suggesting greater postoperative comfort and better overall quality of life.